THE ECONOMICS OF *TROCHUS NILOTICUS*.

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(Plates v.–vi.)

The following was written as a Report from the Special Committee on Marine Biological Economics of Tropical Australia, appointed by the Commonwealth Institute of Science and Industry.

Nomenclature.

This large and handsome shell was mistaken for a product of the River Nile by Aldrovandus, who, in 1606, was the first writer in Europe to describe it. Thus Linnæus in 1767 adopted from him the title of *Trochus niloticus*. Other scientific names that it has since received are *Trochus spinosus* Gmelin, 1791; *Trochus flammeus* Bolten, 1798; *Trochus zebra* Perry, 1811 (Mathews & Iredale, Victorian Naturalist, xxix., 1912, p. 13); *Trochus marmoratus* Lamarck, 1822; *Astralium pagodus* Wood, 1879 (Hedley, Proc. Linn. Soc. N.S. Wales, xxxiii., 1908, p. 467); and *Trochus montebelloensis* Preston, 1914. In the Philippine Islands it is popularly known as "Chin leh," and at Cape Bedford, Queensland, the aboriginals call it "Dobbi."

Trochus niloticus had long been considered (Lamarck, Syst. An. s. vert., 1801, p. 85) as the type of the genus *Trochus*. But Iredale (Proc. Malac. Soc. x., 1912, p. 225) notes that not being one of the original party, it is inadmissable, and designates *T. maculatus* as the type. As a sectional name *Pyramidea*, Swainson, may be appropriated by *T. niloticus*.

Description of the Shell.

The remarkable feature of *T. niloticus* is the grotesque expansion of the last whorl. In the related *T. maximus*, not yet recorded from the South-west Pacific, the normal angle of the spire is continued as usual to the last. But in *T. niloticus* a bulge commences in the penultimate whorl, and increases rapidly, carrying the last whorl out of alignment with the rest. So that the last whorl approaches the horizontal, and the aperture, from being twice as broad as high, becomes three times as broad as high. Finally the insertion of the lip tends to drop below the periphery.

As with other large species, the summit is so severely eroded that the upper whorls cannot be counted on any adult individual. By combining measurements of a young, of a half grown, and of a large shell, I arrived, as follows, at an estimate of fourteen whorls for a complete specimen. In the youngest example used, having a maximum diameter of fifteen millimetres, the earliest, or at least one whorl, had already vanished. The presumed second whorl is 1 millimetre in diameter, the third $1\frac{1}{2}$; the fourth 2; the fifth 4; the sixth 5; the seventh $7\frac{1}{2}$; the eighth 12 mm. Now changing to the medium shell, that whorl which has a diameter of 12 mm. is presumed to be the eighth; accordingly in this individual the seventh whorl is 8 mm.; the eighth 12; the ninth 19; and the tenth 30. Again changing to the largest shell, that whorl which has a diameter of 30 is regarded as the tenth, and thus proceeding, the ninth whorl has here a diameter of 20; the tenth 30; the eleventh 42; the twelfth 64; the thirteenth 91; and the last and fourteenth 142 mm. (say $5\frac{1}{2}$ inches). The minor diameter of this measured shell (Figs. 1, 2) from Samarai, Papua, is 123 mm., the height 120 mm.; the weight is a pound and a half. No such size has, so far as I am aware, been recorded in literature. Fischer (Monogr. Trochus, 1880, p. 67), gives the breadth as 140 mm., the height as 95 mm. The largest specimen which von Martens had examined was only 124 mm. in breadth; this he contrasted with a dwarf only 61 mm. high and 67 broad (Martens, Ann. Mag. Nat. Hist. (3) xx. 1867, p. 99). Other Samarai shells have a diameter of 141, 137, 135, and 129 mm., and another from Torres Strait is 133 mm. The correspondent, to whose kindness I owe this material, writes of giants from Samarai of eight inches diameter, which he has seen. Such would probably have an additional half whorl.

Nothing definite is known of the age of *T. niloticus*. According to native tradition in Fiji, the mollusc lives for four years ; the youngest stages are passed in deep water on the reefs, a shell at two inches diameter is thought to be six months old, at three inches one year, and at four inches two years, the rate of increase becoming slower as growth proceeds.

The upper and lower whorls are diversely sculptured. For the first eight whorls, in the *pagodus* stage (Fig. 5) the periphery carries projecting, imbricating, hollow, arched scales at about 14 to a whorl. A transition stage, that of *spinosus* (fig. 4) follows, in which, for a whorl or two these scales are gradually modified into obliquely compressed tubercles and then vanish, leaving the peripheral keel quite smooth. In this family, such scales are a usual feature, reaching especial development in *Astrea heliotropium*, *Guildfordia triumphans*, *Angaria delphinula* and *Turbo marmoratus*. Even when lost in maturity, these tend, as here, to appear in infancy. They also do so in the case of *Turbo stamineus* (Kesteven, Proc. Linn. Soc. N.S.W., xxvi., 1902, p. 175, Pl. xxxv., f. 2). It is now suggested that these peripheral scales may be a reminiscence of the pore-scales of *Haliotis*. In respect of these scales *T. niloticus* is further developed than such co-generic types as *T. nodiferus* and *T. dentatus* where the scales persist throughout life. On the upper whorls the area between the peripheral scales and the channel'ed suture is occupied by four or five spaced lyrae, the two upper nodulous, the others flat. On succeeding whorls the lyrae first multiply and then disappear gradually. At eight whorls the baes has about fourteen fine, spiral, lyrae, increasing by intercalation and as broad as their interstices. These continue of the same relative importance to the eleventh whorl, after which they gradually fade till scarcely a trace can be distinguished on adult shells.

The axis is a cork-screw shaped columella, the last turn of which is free in the axial funnel, the remainder embedded in the roof of callus above. Below this plait the columella is produced in a longer spiral to a broad, horizontal, knife-like process at the base of the aperture. In young shells the false umbilicus is a narrow, deep, spiral funnel with steep sides, but in senile examples the hollow is filled with a callus pad, nearly flush with the rest of the base. The centre and columella are nacreous, a crescent opposite the aperture is porcellaneous. A similar succession is seen in the inner lip, where the border is porcellaneous and the interior is nacreous. When the shell has been boiled, the fact is shown by superficial, microscopic cracks in the nacre of the axis. The right and left insertions of the lip leave between them an uncovered space of the previous whorl. Only the last four whorls of the adult shell are inhabited, the earlier ones being filled solid with porcellaneous callus. (Fig. 3).

The colour is a white ground painted with zic-zac red flames as broad or broader than their interstices and descending forwards across the line of growth, and ranging from light pink to dark purple. On the base these flames sometimes break up into cuneiform marks with the points directed backwards. Within the aperture red is often replaced by olive-green, but this is not, as von Martens supposed, a result of the original colour fading. On the upper whorls are a subsutural row of six or seven purple patches, between which are close, narrow, rose-pink lines sometimes appearing on the lyrae as articulations or arrow heads.

In life, the whole shell, except the axial area, is clad in a fibrous epidermis, brittle when dry, frilled into small lamellae set at four to the millimetre. These run down backwards, along the lines of growth but across those of colour. This epidermis does not intrude into the axial funnel.

The operculum (fig. 7) is a thin, flat, round, chitinous plate, 32 mm. in diameter, composed of numerous narrow spirals. Below, it is glazed with chitin deposited after the growth of the spirals and showing a line of muscular attachment. In the centre is a minute pivot knob, on which the whole operculum revolves. On the upper surface is a small, corresponding axial pit. These features seem not to have been previously observed.

The upper side is in life probably raised in a low cone, for the middle is abraded. For this reason it is impossible to count the whorls which obviously exceed ten. Probably the operculum corresponds whorl for whorl with the shell, thus making fourteen. On the outer spiral is a dark border and a fringe along which a subsequent spiral would be wound.

The animal was illustrated by Quoy and Gaimard (Voy. Astrolabe, Pl. 62, fig. 12). It is curious that no epipodial filaments are shown by them. The left cervical epipodium is shown unslit, as it appears in a smoke-dried specimen before me. The radula was figured by Troschel (Das Gebiss der Schnecken, ii., 1879, p. 224, pl. xxi., fig. 11, a-d).

On what kind of sea-weed the Trochus feeds, what eggs it lays and where, as well as most details of its life-history are unknown.

Though the sexes are separate, there is no distinction between the shell of a male and of a female animal. The reproduction of the species was studied in New Caledonia by Mr. Montague (P. D. Montague, Revue Agricole de la Nouvelle Caledonie, No. 45, 1915, pp. 39-43, plate I.). who unfortunately was unable to continue his researches throughout the year. In shells of a diameter of from 10 to 12 cm. (4½ inches) he found the ripe sexual glands to extend over almost all the liver, at the summit of the coil, grey in colour in the male and dark green in the female. At the end of December the ovaries of several specimens, 9 cm. in diameter, were distended with eggs ready for deposition. A series of specimens ranging from 7 to 8.5 cm., examined in October and May, showed the sexual glands to be small and undeveloped.

Mr. Montague concluded, firstly, that the eggs were laid early in the year; secondly that the animals of shells less than 8.5 cm. (3½ inches) are incapable of reproduction. The latter conclusion is, however, only tentative.

Geographical Range.

The real home of this mollusc is not, as early writers supposed, in any river, but on coral reefs. It ranges from Ceylon (Hanley in Tennent, Ceylon, i., 1859, p. 241) in the west, to Samoa (Schmeltz, Mus. Godeffroy, Cat. iv., 1869, p. 101) in the east, and to the Loo Choo Islands (Pilsbry, Cat. Mar. Moll. Japan, 1895, p. 179) in the north. In Australia it was recorded by Brazier from Torres Strait and by Tenison Woods from Port Douglas (Proc. Linn. Soc. N.S.W. ii., 1878, p. 42 and v., 1880, p. 116). From the Monte Bello Islands in Western Australia it has apparently been described as *Trochus montebelloensis* (Preston, Proc. Malac. Soc., xi., 1914, p. 16, fig.). For food it was used by the New Caledonians (Fischer, Journ. de Conch. vii., 1859, p. 331), by the islanders of Torres Strait (Jukes, Voy. Fly, i., 1847, p. 178), and by the natives of Cape Bedford, Queensland (Roth, North Q'land Ethnogr. Bull. iii., 1901, p. 19). The periphery of the shell was cut out, smoothed and worn as a bracelet by the Papuans (Edge-Partington, Ethnographic Album, First series, part 2, 1890, Pl. 289, fig. 5; Pl. 290, fig. 7). But among civilised people it was only known to shell fanciers until a few years ago.

Fishing.

Exhaustion of former supplies of pearl shell and the increasing demand of recent years, has promoted search for new sources of mother-of-pearl. Thus *Trochus niloticus*, or trocas, as it is sometimes called, having dense firm nacre which proved good material for buttons, came to be exploited by manufacturers. During the past six years an active request for Trochus by button makers has sprung up, advancing from twenty to thirty pounds a ton. The requirements of the manufacturer are that the shell shall be at least an inch and a half in diameter, taken in a living state, not encrusted with algal or coralline growths, nor penetrated by marine borers. According to Mr. Seale's figures, a row of buttons is cut from the outside of each whorl, two rows from the base and another from the partition wall within. Frequently these buttons show their origin by a trace of pink at the underside.

Vessels formerly engaged in gathering pearl shell are now often diverted to this work. The Great Barrier Reef is being fished for Trochus from Torres Strait southward to Port Mackay. The export of Trochus from Queensland in 1915 was 544 tons worth £12,000 and in 1916 was 950 tons worth £23,000. The Philippine Islands export about 320 tons annually. From Western Australia the exports of Trochus were: for 1912, 52 tons; for 1913, 66 tons; for 1914, 19 tons; for 1915, 73 tons; for 1916, 26 tons. There are large fisheries in New Guinea, the Solomon Islands and Fiji, of the product of which I have no particulars.

Trochus is taken by hand on the coral reefs between tide marks, but most is gathered by coloured naked divers in about two fathoms and some even as deep as six fathoms. In the deeper water search is made from the boat with a water telescope and in the water the divers use Japanese water goggles. The extreme record of depth is a statement (Watson, Rep. Chall. Zool. xv., 1886, p. 50) that the "Challenger" dredged *T. niloticus* in 12 fathoms off Levuka, Fiji.

Cleaning is done in different ways. The shell brings a better price if the attached growths and lime crusts are pared away. Sometimes the catch is arranged by spreading the shells, still containing the animal, on the beach for the blow flies to dispose of the flesh. The putrid shells are afterwards washed clean in the sea. If the shells are left too long exposed they suffer by bleaching from sun and rain and the nacre is dulled. A quicker and cleaner method is to boil out the snail, but this has the detrimental effect of slightly cracking the nacre. Sometimes a mixture of both processes is adopted, the shells being first placed in hot or boiling water for twenty minutes, then put aside to decay slightly, till the animal can be extracted with a crooked wire. The best way, that of burying in sand for a short time, does not seem to be practised in the Pacific.

But the more careful of the Japanese fishermen save both meat and shell. From ten tons of shell a ton of meat is obtainable, worth in China £20 a ton. After boiling for half an hour, the entire snail is shaken out of the shell, dried and smoked for two days. It is then ready for export. In China this smoked Trochus is esteemed a dainty. It is soaked in cold water till soft, cut into dice, and used as a base of a soup, like beche-de-mer soup. Mr. E. J. Banfield, who supplied me with this information, tried this Trochus soup and reports it as very palatable.

Trochus obeliscus, which is called "wabisi" at Samarai, is too thin to be of value. But an expert, Mr. W. P. Cottrell, assured me that *Angaria delphinus* would be excellent material if available in sufficient quantity.

Regulations.

In Queensland the Government require a license at the rate of £3 per annum for the first ten tons, and 10s. for each additional ton, of the vessels engaged. The man in charge is also licensed at £1 a year. At Samarai, a license is charged of £1 per annum for each cutter or lugger and 10s. for each dingy or canoe.

In the Philippines it is illegal to take Trochus under eight centimetres (say three inches) diameter. (Seale, Philippine Journ. of Science xi., 1916, p. 262). After the reefs of New Caledonia had been exhausted by over fishing, a minimum size of 8 cm. and a close season were imposed (Compton, Geograph. Journ. xliv., 1917, p. 91). Because it is understood that the Trochus breeds in the warmer season, fishing is there permitted only from 1st April to 1st November.

Neither in Australasia, nor in other British possessions, are any limits set for the size or season, at which Trochus may be taken. The smallest size specified by Japanese buyers is 1½ inches. It has been suggested by the Suva Chamber of Commerce that a legal minimum of 2 or 2½ inches for the "chicken" shell would be beneficial to the industry. Some measure of natural protection is afforded by the fact that it is too troublesome and unprofitable to pick out the snails from the smallest shells. If the natives are correct in asserting that the Trochus come up from deep water on the reefs during the south-east monsoon, then it is probable that the species is preserved during its early stages in rough and inaccessible places at the base of the outer reefs.

The annual Australian crop is likely soon to deteriorate under the present active fishery.

EXPLANATION OF PLATES V–VI.

Fig. 1 and 2.—Front and base view, slightly reduced, of a specimen of *Trochus niloticus* from Samarai, 5½ inches in diameter.

Fig. 3.—A shell divided vertically to show the vacated upper chambers, blocked by porcellaneous callus, and to show the pearly frame of the shell, lined and coated with lon nacreous layers, reduced.

Fig. 4.—Young specimen an inch in diameter, showing peripheral tubercles; enlarged.

Fig. 5.—Type specimen of *Astralium pagodus* showing an earlier stage in which the tubercles were preceded by projecting scales; magnified.

Fig. 6.—A shell from which button discs have been cut, drawn after Mr. Seale's photograph; reduced.

Fig. 7.—Operculum, to show the numerous spirals, the pivot knob on which the whole rotates and the muscle scar of the under side; reduced.

Fig. 8.—Sector of same, upper side, enlarged.

Fig. 9.—A Papuan bracelet cut from the periphery of *Trochus niloticus*; reduced.